ARMY RESEARCH LABORATORY

Review of Integrated Modeling and Optimization Software for Advance Concepts Branch Models

by Andrew A. Thompson

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Contents

List of Figures

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1. Introduction

The U.S. Army Research Laboratory (ARL) Advanced Weapon Concept Branch uses a number of models to evaluate weapon effectiveness. Many studies are performed by a serial combination of existing models, and in some situations this can be difficult and time consuming. The Integrated Modeling and Optimization (IMO) software, developed by RDAR-MEM-L, Armaments Research, Development, and Engineering Center, U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ, was investigated to determine if it had the potential to be a useful tool to combine models. The software is currently being used at ARDEC and has sped up their ability to perform studies based on their collection of models.

2. Basic IMO Use

Although a user's manual exists for the IMO software, its basic use will be discussed. An analysis using IMO produces a set of values. These values are the various inputs and outputs required by the individual models in the sequence. The sequence of models is referred to as a workflow. Each model is inserted into a workflow after being placed in a shell, which is the basic unit used by the IMO software.

A shell is the IMO information required for the IMO software to run a particular model. Typically, when a workflow is run, the investigator wants to quantify the relationship between specific variables (inputs and outputs). To set up a shell for a specific model, three categories of information must be identified. First, the location of the desired inputs within the input file must be identified, and second, the location of the desired outputs in the output file must be identified. Both the input and output files for the specific model must exist before making the shell. Input files are typically supplied with the software; however, the analyst may need to develop an appropriate input file. The required output file is the one that corresponds to the input that will be used. This is important to note because in many instances the format of the output file can be dependent on the input file. Rather than using a supplied output file, it is good practice when using IMO software to run the model software with the desired input file to create the appropriate output file. The third category to be identified is the information necessary to run the model in an automated fashion. Typically, this includes the command line to run the model and any ancillary files that are required by the model. After these tasks are completed, creating a shell within the IMO software is straightforward.

A study typically proceeds by chaining a sequence of shells together, or creating a workflow. To form a workflow, the shells must be entered in the proper sequence and then the shells must be connected. The connection between shells is the designation as to which of the output variables (designated by the preceding shell) connect to the inputs of the current shell. After a workflow is established, an analysis can be performed.

The goal of the IMO software is to allow the investigator to run an analysis. In addition to chaining models together, the IMO software keeps track of the input and output variables associated with each shell. This information is placed in a database that can be used to answer the questions that spurred the investigation. The software allows several methods to select input variables. The user selection method is the most general; parametric and factorial methods are also included for user convenience. The software also includes a post processing section that allows graphing of selected variables.

The IMO software was developed in the MATLAB language. It comes as stand-alone software but requires the installation of a library of the MATLAB functions that it uses. The software comes with a series of videos that show how to perform various tasks using the IMO software.

3. Issues with Various Branch Models

3.1 FBAR

The U.S. Army Materials Analysis Activity (AMSAA) developed the FBAR model to answer questions related to a single weapon firing at an area personal target. It reports the expected fraction of casualties. The model evolved from 1979 until 1995. The expected fraction of casualties is s typical measure of effectiveness for a study and typically FBAR would be the last model in a chain.

By placing FBAR in a shell, the inputs and outputs were easy to designate within the IMO software; however, instructions to run the model in an automated fashion presented a difficulty. FBAR is set up to query the user for the name of the input file and then query for the name of the output file each time it executes, but because the IMO software is set up to automatically rerun the model with modified input files, a problem arose. A solution was found by using the redirection operator ‘<’ in the IMO shell field for running the model. Placing the name of the input and output files on sequential lines of a text file and then using the redirection operator to provide input from the text file nullified the issue.

After placing FBAR in a shell, it was possible to run parametric studies using the IMO software. This was accomplished by creating a workflow that only contained the FBAR shell. Using this workflow, it was simple to create an IMO analysis that varied the values of selected input variables and then observe the effect on the predetermined output variable. To observe a different combination of input and output variables would require a different shell.

3.2 IBHVG5

The IBHVG5 model was developed by the Ballistic Research Laboratory to simulate the interior ballistic cycle. The code is rich with parameters related to interior ballistics. By default, IBHVG5 prints its output to the screen; thus when making an IMO shell, redirection must be used to direct the output to the appropriate file. Before creating a shell, there must be an output file so the model must be run and the output redirected to the desired file. Once this is done, it is straightforward to go into the IMO software and create a shell. Note that for the run command line of the shell, redirection for the input file uses ‘<’ and ‘>’ for the output file. When used within the IMO software, the user should ignore any feature of a model that allows for parametric and Monte Carlo runs since this will be controlled by the analysis phase of the IMO software.

3.3 YTRAJ

YTRAJ is an exterior ballistic model developed at ARL and described in Yager.[1] Based on a set of inputs, a trajectory is calculated. This model fit into a shell quickly in a straightforward manner. Note that in some situations it may be necessary to insert models related to data transformations. These transformations can typically be performed in MATLAB, Excel, or some other general purpose language.

3.4 CASRED

The casualty reduction model, or CASRED, was designed by AMSAA to investigate the effectiveness of fragmenting munitions. Many situations and parameters relate to a collection of files that are required to run the model. Many of these files are in a directory that is defined within CASRED by a relative directory structure. This means that the files are expected to be in a specific location relative to the executable file. This presented difficulties for the IMO software due to the way IMO works in running an analysis. The IMO software creates subdirectories for each run sequence it completes. In each subdirectory are an executable file, the input file, and the other ancillary files included when setting up each shell. The version of the IMO software tested did not contain provisions for dealing with the relative directory structure, which is common to UNIX systems. There are two obvious solutions to this problem. First, the CASRED code could be altered. Although this could work for CASRED, it would not be an option for a situation where the source code was not available. A second option was suggested by the IMO developers: design a MATLAB code that copies the desired directory structure before each run. The developers also mentioned that there would be new runtime options in future versions of the IMO software and that newer versions would provide a simple solution to this problem.

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[1] Yager, R. J. *A Two-Dimensional, Numeric Technique for Approximating the Trajectory of a Rocket/Projectile Using C++*; ARL-TR-4608; U.S. Army Research Laboratory: Aberdeen Proving Ground, MD, October 2008.

4. Proof of Concept

It was decided that a combination of two models would constitute an IMO software proof of concept for branch models. This was accomplished by combing the IBHVG5 model with YTRAJ, with IBHVG5 used as the first shell and YTRAJ as the second. The charge weight was used as an input variable to IBHVG5 and the output variable of interest was muzzle velocity. For the YTRAJ model, the input variable of interest was muzzle velocity and the output variable was angle of fall. After constructing the workflow, the IMO software ran the desired cases and collected the desired information, as shown in figure 1, which was produced using the post processing section of the IMO software.

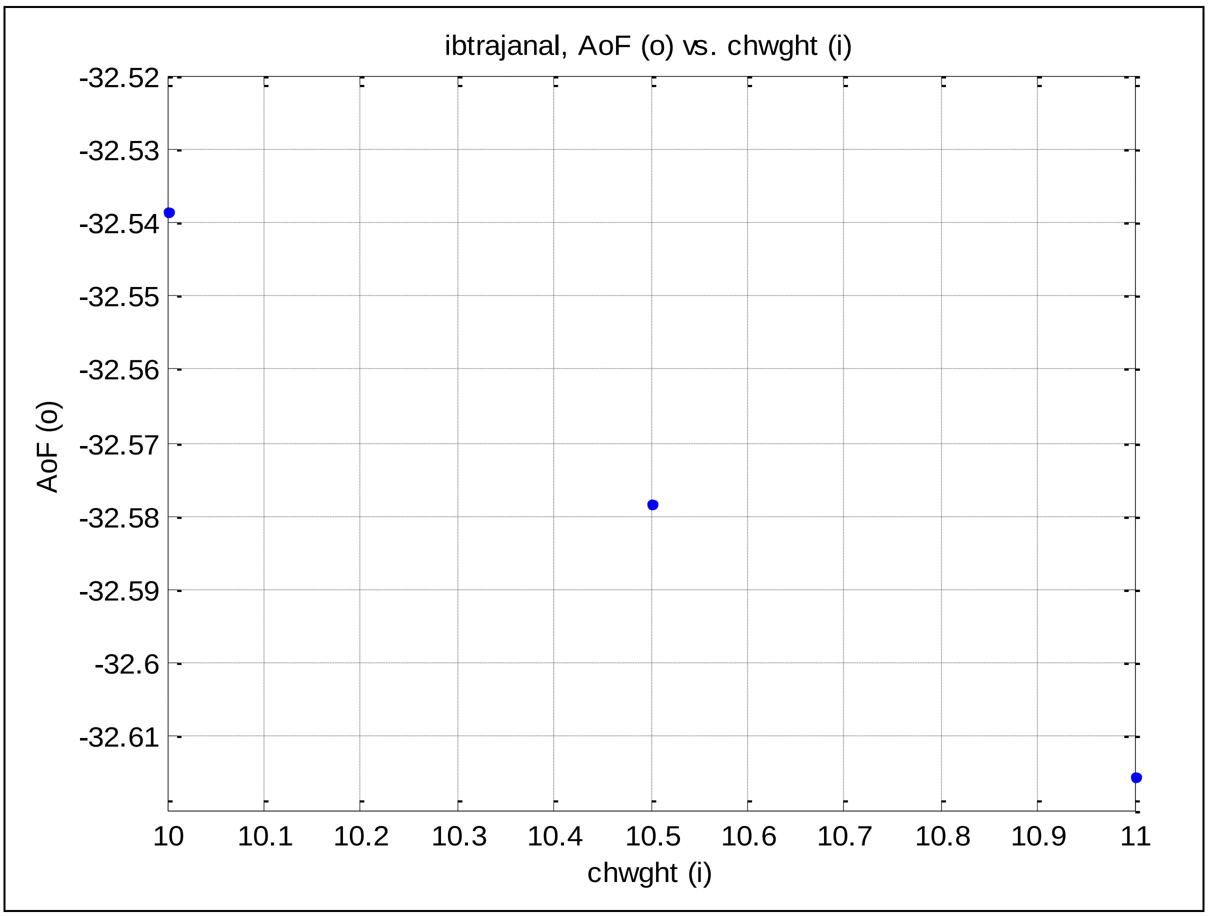

Figure 1. Graph of charge weight and angle of fall.

5. Discussion

The IMO software would allow the sequencing of many diverse models. This would probably mean that the analyst would need to spend less time considering how to develop a sequence of models and thus the time involved with data transforms between models and extracting data from output files would be diminished. The ease with which the outputs of one model can be connected to the inputs of a subsequent model is a strength of the IMO software. This feature can save hours of the string programming required to manipulate input and output files. The IMO software provides a framework for an analyst to quickly answer questions that require a sequence of models to investigate.

Alternates to the IMO software include the use of languages that can make system calls to run models; MATLAB or Python would provide a way to sequence models. In these cases, the extraction of data from the output of a model would be done on a case by case basis. Analysts sometimes can modify software to call other models and then perform the desired data extraction. Either of these approaches provides reasonable alternatives to the use of the IMO software.

The IMO software is probably more useful for externally developed models than those developed internally. For internally developed models, as previously mentioned, it may be straightforward for the developer to make modifications to the models that facilitate answers to a specific question. For models or simulations developed by an external organization, it is typically not possible to alter the executable code of the model and source code is often not provided. For some software, only a committee can authorize source code modifications. In these cases, the IMO software can provide a framework for sequencing models.

The IMO software is easy to learn and straightforward to use. An analyst can learn how to use the package in a short time. At this point in time, the developer's response to questions is excellent, so the user does not have to be concerned about lack of understanding of the workings of the software. If there are questions that require a sequence of models to answer, the IMO software provides a straightforward path to attain this goal. If an organization has a collection of software products that require sequencing, the IMO software provides a metamethod for operations.

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